Role of CD44 Variant Exon 6 in Invasion of Head and Neck Squamous Cell Carcinoma

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Objectives: To determine the correlation between the expression of CD44 variant exon 6 (v6) and the clinico-pathological features of head and neck squamous cell carcinomas (HNSCCs), and to study the role of CD44v6 in cell invasion using a human HNSCC cell line (HSC-2).

Design: The expression of CD44v6 was evaluated using immunohistochemical analysis in paraffin-embedded tissue specimens from 89 primary lesions. The concentration of CD44v6 protein in 37 cryopreserved tumor specimens was evaluated using the enzyme-linked immunosorbent assay. The HSC-2 cells were treated with 2F10, a monoclonal antibody against CD44v6. The effects of 2F10 on HSC-2 cell proliferation, migration, and invasion potential were evaluated.

Results: The down-regulation of CD44v6 expression or the concentration of cancer tissue significantly correlated with a lower degree of pathohistological differentiation and a higher rate of cervical metastasis. The invasion of HSC-2 cells into type I collagen gel and the expression of CD44v6 were decreased in invading cells released from the upper layer. Furthermore, the treatment of HSC-2 cells with 2F10 significantly enhanced cell invasion. However, 2F10 did not affect either the proliferation or migration properties of HSC-2 cells.

Conclusions: The down-regulation of CD44v6 expression may be useful as a biological marker for the degree of malignancy in HNSCCs. We assume that the loss or dysfunction of CD44v6 is involved in the acquisition of invasion ability in HSC-2 cells. In addition, the potential existence of a CD44v6-mediated signal transduction pathway may play a role in inhibiting the invasion in HNSCCs.


LYCOPROTEIN CD44 is a cell surface molecule that appears to be involved in cell-cell and cell-matrix interactions. It also appears to mediate several other functions, such as lymphocyte homing, T-cell activation, and tumor metastasis. The CD44 gene measures 50 to 60 kd, resides on chromosome 11p13, and is known to be composed of at least 20 exons. Ten of the exons are constitutively expressed on almost all cell types to produce a heavily glycosylated 85- to 90-kd isoform known as the CD44 standard form (CD44st). The remaining exons can be alternatively spliced to produce various isoforms, which are called CD44 variants (CD44v).

In 1991, the expression of some variant exons, including CD44v6, was shown to distinguish metastatic from nonmetastatic pancreatic carcinoma in the rat. Evidence that CD44 itself plays a role in metastasis was based on the fact that transfection with complementary DNA encoding those exons converted nonmetastatic rat carcinoma cells into metastatic cells. Furthermore, the coinjection of antibody against CD44v6-encoded peptides with metastatic cells also suppressed their metastatic behavior. Although in humans the functions of CD44v remain unclear, they are considered to play an important role in the growth and metastasis of several kinds of tumors. Attention has been drawn to the recently published report by Takahashi et al. that CD44 plays a role in such signal transductions as cell-cell and cell-matrix interactions and thus regulates matrix metalloproteinase (MMP). They reported that cell invasion and cell migration increased and up-regulation of MMP-2 was observed in a melanoma cell line following treatment with the monoclonal antibody for CD44st.

Recent clinicopathological studies have revealed that the expression of individual variant exons was altered in several malignancies. For example, the expression of CD44v6 in gastric, colon, and breast cancers and non-Hodgkin lymphoma...
phoma\(^1\) was found to be associated with shorter survival. In contrast, other reports have shown the expression of CD44\(^t\) to be associated with longer survival in neuroblastoma,\(^2\) while the down-regulation of CD44\(^v6\) is associated with shorter survival in laryngeal squamous carcinoma.\(^3\) The relationship between the clinical features and the expression of CD44 isoforms in each organ remains a controversial issue. However, it is reasonable to say that the expression of the CD44 gene is specifically regulated in each organ.

In the treatment of head and neck squamous cell carcinomas (HNSCCs), the management of cervical lymphatic metastasis and primary lesions is one of the most important factors contributing to a favorable prognosis. However, cervical lymphatic metastasis cannot always be predicted from the size and extent of invasion of the primary lesion.

### Table 1. Clinical Stage and Pathological Differentiation of Head and Neck SCCs (Immunohistochemical Analysis)*

<table>
<thead>
<tr>
<th>SCC Type</th>
<th>No. of Patients</th>
<th>Clinical Stage, No.</th>
<th>Pathological Differentiation, No.</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Oropharyngeal</td>
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<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Hypopharyngeal</td>
<td>18</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Tongue and mouth floor</td>
<td>35</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>89</td>
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</table>

*SCCs indicates squamous cell carcinomas.
†One patient had distant metastasis.
The effect of the monoclonal antibody 2F10 against CD44v6 on the proliferation of HSC-2 cells was assessed. The number of viable cells was determined by using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. Next, $5 \times 10^5$ HSC-2 cells in a single-cell suspension with MEM were added to a 96-well microtiter plate (Coster Co, Cambridge, Mass). After 24 hours of incubation, the medium was completely removed and various doses of 2F10 were added. Following an additional 48 hours of incubation, the number of viable cells was measured. All experiments were performed in triplicate.

**CELL PROLIFERATION ANALYSIS**

The transfilter migration activity of HSC-2 cells was evaluated in a 24-well transwell (pore size, 8 µm) (Becton Dickinson, Bedford, Mass). The upper wells were seeded in serum-free MEM containing $5 \times 10^5$ HSC-2 cells with various doses of 2F10. The lower wells were filled with HT-1080 supernatant, which served as a chemottractant. After a 6-hour incubation at $37^\circ$C in an atmosphere containing 5% carbon dioxide, the cells that had not migrated to the upper surface of the membrane were removed by wiping gently with a cotton swab. Cells on the reverse side of the filter were fixed and stained with Diff-Quik (International Reagents Co, Kobe, Japan). After the inner chamber was washed in tap water, the number of migrating cells in 10 random fields was counted using light microscopy at high power ($\times 400$), and the mean ± SD was calculated. All experiments were performed in triplicate.

**CELL MIGRATION ASSAY**

The transfilter migration activity of HSC-2 cells was evaluated in a 24-well transwell (pore size, 8 µm) (Becton Dickinson, Bedford, Mass). The upper wells were seeded in serum-free MEM containing $5 \times 10^5$ HSC-2 cells with various doses of 2F10. The lower wells were filled with HT-1080 supernatant, which served as a chemottractant. After a 6-hour incubation at $37^\circ$C in an atmosphere containing 5% carbon dioxide, the cells that had not migrated to the upper surface of the membrane were removed by wiping gently with a cotton swab. Cells on the reverse side of the filter were fixed and stained with Diff-Quik (International Reagents Co, Kobe, Japan). After the inner chamber was washed in tap water, the number of migrating cells in 10 random fields was counted using light microscopy at high power ($\times 400$), and the mean ± SD was calculated. All experiments were performed in triplicate.

**CELL INVASION ASSAY WITH ORGANOTYPIC RAFT CULTURE**

In vitro tumor invasiveness was evaluated according to the procedures described previously, with some modifications. In a 6-well multiplate (Coster Co), $5 \times 10^5$ HSC-2 cells suspended in 1 mL of medium (DMEMF-12 plus 10% FBS) were seeded on gels containing $3 \times 10^5$ primary culture fibroblasts in 3 mL of 0.2% type I collagen neutral medium (CELLGEN; Koken Co, Tokyo, Japan). After 24 hours of incubation, the gels were detached from the wells and floated below the surface of the medium. The DMEMF-12 medium containing 10% FBS (3 mL/well) was changed every 2 days. The culture medium and gels were supplemented with various doses of 2F10. After 10 days, the composite gels were fixed with 10% neutral formalin for 15 minutes, embedded in paraffin, sectioned, and stained with hematoxylin-eosin or subjected to immunohistochemical analysis. The tumor cells that had become detached from the stratified layer and migrated into the underlying collagen gel were counted as invading cells. The number of invading cells in 5 random fields of each culture was counted under light microscopy ($\times 200$), and the mean ± SD was calculated. All experiments were performed in quadruplicate.

**MMP-1 IMMUNOASSAY**

For this assay, $1 \times 10^5$ HSC-2 cells suspended in 100 µL of medium (DMEMF-12 plus 10% FBS) in a single-cell suspension were added to a 24-well plate (Coster Co). After a 24-hour incubation, the medium was completely removed and various doses of 2F10 were added. After another 24 hours of incubation, the culture medium was filtered through a 0.22-µm Millipore filter before analysis. The conditioned medium of each well was quantified using an MMP-1 human ELISA system (Biotrak; Amersham Pharmacia Biotech Inc, Piscataway, NJ) according to the manufacturer’s instructions. Data are presented as the mean ± SD from triplicate experiments (detection limit, <1.7 ng/mL).

**STATISTICAL ANALYSIS**

For the statistical analysis of the expression of CD44v6, a nonparametric statistical test (Mann-Whitney test or Kruskal-Wallis test) was used. In the study of HSC-2 cell lines in vitro, data are expressed as mean ± SD. Statistical analysis was performed by means of 1-factor analysis of variance, and P values were calculated by the Fisher protected least significant difference method. P < .05 was considered statistically significant.

**CORRELATION BETWEEN CD44v6 CONCENTRATION AND CLINICAL CHARACTERISTICS: ELISA**

The overall mean (SD) concentration of CD44v6 in HNSCC tissues was 1.7 (1.5) µg/mg. The mean (SD) concentrations of CD44v6 were 2.2 (1.8) µg/mg in well-differentiated carcinomas and 1.22 (1.08) µg/mg in moderately and poorly differentiated carcinomas. Down-regulation of CD44v6 concentration was significantly correlated with a poorer degree of differentiation (P = .03) (Figure 2A). The mean (SD) CD44v6 concentrations were 2.1 (1.2) µg/mg in the...
group with stage T1 and T2 tumors and 1.3 (1.8) µg/mg in the group with stage T3 and T4 tumors. With an increase in tumor size, the CD44v6 concentration in the tumor decreased significantly \( (P=0.02) \) (Figure 2B). The mean (SD) CD44v6 concentrations in cancer tissue were 1.05 (0.87) µg/mg for the group with cervical metastasis and 2.3 (1.7) µg/mg for the group without cervical metastasis, a significant difference \( (P=0.008) \) (Figure 2C).

**CD44v6 EXPRESSION IN THE HSC-2 CELL LINE**

The expression of CD44V6 was shown by immunostaining for HSC-2 cells; staining occurred chiefly in the cell membrane (Figure 3).

**EFFECT OF 2F10 ON HSC-2 CELL PROLIFERATION, MIGRATION, AND INVASION**

There was no difference in the cell proliferation and cell migration potential of HSC-2 cells in the presence of 2F10 at 0.1 and 1.0 µg/mL as compared with the controls (Figure 4A-B). However, in the invasion assay, the invading cell count was significantly higher in the presence of 2F10 at 0.1 µg/mL \( (P=0.01) \) and 1.0 µg/mL \( (P=0.04) \) as compared with the controls (Figure 4C, and Figure 5A-B). Moreover, in comparison with the CD44v6 immunostaining of the control specimens, CD44v6 expression of HSC-2 cells that invaded the gel after release from the cell population on the
EFFECT OF 2F10 ON MMP-1 EXCRETION POTENTIAL OF HSC-2 CELLS

The mean (SD) MMP-1 concentration in the culture medium was 1008.6 (50.3) ng/mL for the cells without treatment (controls) and 1100.6 (120.4) and 1189.3 (360.1) ng/mL, respectively, for the cells treated with 2F10 at 0.1 and 1.0 µg/mL. An up-regulation in MMP-1 excretion was found in response to treatment with 2F10. Moreover, in the presence of 2F10 at 1.0 µg/mL, the MMP-1 concentration increased significantly as compared with the controls \( (P = .04) \) (Figure 6).

COMMENT

Adhesion molecules play an important role in the invasion and metastasis of cancers. Since Günther et al reported in 1991 that CD44v is a factor related to the metastatic properties of cancer, the relationship between CD44v and the invasion or metastasis of cancer has been further investigated at many institutions. We confirmed an abnormal expression of CD44v in bladder, colon, and breast cancers using reverse transcription—

<table>
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<tr>
<th>Clinical Factors</th>
<th>No. of Patients (N = 89)</th>
<th>Mean Expression of CD44v6†</th>
<th>P</th>
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<td>Primary lesion (SCC)</td>
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<td>2 4 6 24</td>
<td>.17‡</td>
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<tr>
<td>Hypopharyngeal</td>
<td>18</td>
<td>1 1 3 13</td>
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<tr>
<td>Tongue and mouth floor</td>
<td>35</td>
<td>1 0 6 28</td>
<td></td>
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<td>T stage</td>
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<tr>
<td>T1-T2</td>
<td>61</td>
<td>3 3 12 43</td>
<td>.91‡</td>
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<tr>
<td>T3-T4</td>
<td>28</td>
<td>1 2 3 22</td>
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<td>N stage</td>
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<tr>
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<td>37</td>
<td>0 0 6 31</td>
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<td>N1-N3</td>
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<td>Well</td>
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<tr>
<td>Moderately</td>
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<tr>
<td>Poorly</td>
<td>13</td>
<td>4 1 1 7</td>
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</table>

*SCC indicates squamous cell carcinoma.
†Percentage of cancerous cells stained. Minus sign indicates less than 5% or no expression; 1+, more than 5% to 50%; 2+, more than 50% to 90%; and 3+, more than 90%.
‡Statistical analysis by Mann-Whitney test.
§Statistical analysis by Kruskal-Wallis test.

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polymerase chain reaction. Our results showed that the expression of CD44v differed according to organ and pathohistological type for each cancer. It has been reported3,8-11,20 that CD44v6 is one of the variants of CD44 that is closely related to metastasis and the invasion of cancers. In addition, a positive correlation has been observed between the expression of CD44v6 and the degree of malignancy of colon,9 gastric,8 uterine,20 and breast10 cancers and non-Hodgkin lymphoma.11 In contrast, in neuroblastoma 12 and laryngeal cancers, 13 decreased CD44v6 expression was found to correlate with the degree of malignancy. Therefore, when CD44v6 is regarded as an index of malignancy, organ specificity should be taken into consideration. The CD44v6 expression in HNSCCs shows characteristics different from those of cancers of other sites, which are mostly SCCs. The normal squamous mucosa of the upper airway shows strong staining for CD44v6, and down-regulation of CD44v6 is associated with cancerous changes.21

In this study using immunological staining of clinical specimens from patients with HNSCCs, the down-regulation of CD44v6 was found to correlate with a lower degree of pathohistological differentiation and a higher rate of cervical metastasis. These findings are consistent with previous reports13 on HNSCCs in which a decrease in CD44v6 expression was shown to correlate with the degree of malignancy. The expression of CD44v6 was thus shown to be a biological marker for the degree of malignancy in HNSCCs. However, the results of immunostaining revealed that CD44v6-positive cases (1+ to 3+) account for 96% of all such cases of malignancy. As a result, CD44v6 is of somewhat limited value for prediction of cer-

![Figure 5. Effect of 2F10 on invasiveness of human head and neck squamous cell carcinoma cell line HSC-2 in organotypic raft culture without (A and C) or with (B) 2F10, 1.0 µg/mL. A and B, The invading cell count was higher in the presence of 2F10 (hematoxylin-eosin, original magnification ×80). C, The invading cells show reduction of CD44v6 expression (arrows) (immunohistochemical staining with Mayer hematoxylin counterstain; original magnification ×220).](image1)

Figure 5. Effect of 2F10 on invasiveness of human head and neck squamous cell carcinoma cell line HSC-2 in organotypic raft culture without (A and C) or with (B) 2F10, 1.0 µg/mL. A and B, The invading cell count was higher in the presence of 2F10 (hematoxylin-eosin, original magnification ×80). C, The invading cells show reduction of CD44v6 expression (arrows) (immunohistochemical staining with Mayer hematoxylin counterstain; original magnification ×220).

Figure 6. Effect of 2F10 on the matrix metalloproteinase 1 (MMP-1) concentration by head and neck squamous cell carcinoma cell line HSC-2. Data are means from triplicate experiments. Error bars indicate SDs. The Fisher protected least significant difference method was used to evaluate significance.

![Figure 6. Effect of 2F10 on the matrix metalloproteinase 1 (MMP-1) concentration by head and neck squamous cell carcinoma cell line HSC-2. Data are means from triplicate experiments. Error bars indicate SDs. The Fisher protected least significant difference method was used to evaluate significance.](image2)
vical metastasis. Therefore, we performed a quantitative study using the ELISA method that showed results similar to those obtained by immunological staining. A decrease in CD44v6 protein concentration was thus shown to be closely related to the acquisition of metastatic properties. Regarding the quantification of CD44v6 protein in tumor tissues by the ELISA method, measurement of the cytosol CD44v6 concentration in breast cancer cells has been reported. However, as far as we could determine, there are no previously published reports on these levels in HNSCCs. The above-described protein extraction method is an original technique developed by our group. Therefore, it is difficult to compare our findings with the results of previous reports. Nevertheless, based on these findings, we believe that the down-regulation of CD44v6 closely reflects the degree of malignancy.

Regarding the mechanism for the invasion and metastasis of tumors, we consider the most likely one to be a 3-step model consisting of the adhesion of cancerous cells to an extracellular matrix, the destruction of the matrix, and the migration of cancerous cells into the matrix. The MMPs, whose main function is the degradation of the extracellular matrix, and also some adhesive factor molecules are thought to be involved in these steps, and CD44 may be one of these factors. However, its mode of action remains to be elucidated. It was recently reported that CD44 regulates the function of signal transduction, including cell-cell and cell-matrix interactions. Moreover, Takahashi et al. reported that cell invasion and cell migration were enhanced after the treatment of melanoma cells with monoclonal antibody of CD44 and the up-regulation of MMPs. In the present study, focusing our attention on CD44v6, which showed a correlation with the cervical metastatic rate, we investigated the role played by CD44v6 in invasion and metastasis using HSC-2 cells, a CD44v6-expressing HNSCC cell line, and 2F10, a monoclonal antibody of CD44v6. For the invasion assay, type I collagen gel incorporating fibroblasts was used. This method has been used for cancer invasion models in HNSCCs for many years. Regarding adherent molecules, invasion of collagen gel has been reported to increase after treatment of esophageal cancer cell lines with the monoclonal antibody of E-cadherin. We also confirmed invasion by HSC-2 cells of collagen gel and observed that the expression of CD44v6 decreased in invading cells released from the upper layer. The addition of 2F10 to this system caused a significant increase in the number of invading HSC-2 cells. Following the addition of 2F10, the excretion of MMP-1, which belongs to the collagenase group and mainly degrades collagen type I, increased significantly in HSC-2 cells. However, the addition of 2F10 did not affect either the cell proliferation or cell migration ability of HSC-2 cells. From these results, we assumed that a loss or dysfunction of CD44v6 was thus involved in the acquisition of invasion ability in HSC-2 cells. In addition, a CD44v6-mediated signal transduction pathway may play a role in the inhibition of MMP-1 excretion. However, the level of MMP-1 was determined only by immunoassay (ELISA), and we did not determine the level of the compound in the active form. In the future, we intend to further study the mechanism for regulation of the secretion of other MMPs.

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